

AVIAN RESPONSES TO OBSERVER CLOTHING COLOR: CAVEATS FROM WINTER POINT COUNTS

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ABSTRACT.—As part of a project to determine optimal methods for censusing winter birds with unlimited-distance point counts, we studied the influence of wearing a hunter-orange vest on richness estimates and species' detection probabilities. We did not find a significant difference in the number of species detected between apparel conditions (vest worn, vest not worn). However, separate detection probabilities for three species were associated with whether or not an orange vest was worn (Carolina Chickadee [*Parus carolinensis*, $P = 0.075$]; Tufted Titmouse [*P. bicolor*, $P = 0.009$]; American Goldfinch [*Carduelis tristis*, $P = 0.002$]). For all three species, detection probabilities were lower when a vest was worn, suggesting that these species were repelled by the orange vest. Movement toward or away from a color, respectively, may generate inaccurate assessments of behavior, habitat use, and abundance. Knowledge about chromotropic responses to observer apparel will enable investigators to design more valid research. A clear benefit of improved designs will be more accurate inferences, which are crucial for conservation efforts and for advancing ornithological science. Received 7 Jan. 1993, accepted 6 May 1993.

Many species of birds use plumage color to discriminate between sexes (e.g., Noble 1936). Conspicuous colors also may signal an individual's rank within a flock (Rohwer 1985), and responses to color can influence the maintenance of pair bonds (Frankel and Baskett 1963, Goforth and Baskett 1965). Colored objects attached to birds also elicit responses (Lensink 1968, Wilson et al. 1990). For example, colored leg bands have influenced mate choice, reproductive success, mortality, parenting behavior, and territory loss (Burley 1981; Burley et al. 1982; Burley 1985a, 1986a, 1986b; Metz and Weatherhead 1991; cf Weatherhead et al. 1991).

It is therefore reasonable to hypothesize that some birds may respond to the color of clothing of researchers. We are not aware of any research that has quantitatively assessed the effects of clothing color on bird behavior, yet such work is essential for determining whether clothing color alters bird behavior and generates artifacts in data sets. If observer apparel induces positive or negative chromotropism—movement toward or away from a color, respectively—researchers may get inaccurate censuses and draw invalid inferences about habitat use, population trends, and numerous other patterns. Such effects could ultimately result in inefficient or misdirected conservation efforts.

As part of a study to identify optimal methods for censusing winter birds with unlimited-distance point counts (Gutzwiller 1991, 1993), we

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examined the influence of wearing a hunter-orange vest on richness estimates and species' detection probabilities. During the winter, investigators may wear an orange vest as a safety precaution because hunting seasons often coincide with efforts to assess winter habitat needs or winter population sizes. We view this analysis as one facet of a larger set of experiments that should be conducted on responses to observer clothing color. In this paper our objectives are to (1) alert investigators to the possibility that avian responses to clothing color may influence census accuracy, (2) describe how species richness and the detection probabilities for individual species in our study were associated with whether the observer wore an orange vest or not, and (3) indicate ways by which biases originating from responses to color can be avoided or reduced.

STUDY AREA AND METHODS

Point counts were conducted in woodlands of the Blackland Prairie and Grand Prairie regions (Riskind and Diamond 1988) within 50 km of Waco, Texas (31°33'N, 97°10'W). Details about soils, vegetation, and weather are in Correll and Johnston (1979), Gehlbach (1991), and Gutzwiller (1991).

Data collection.—KJG recorded the number of individuals of each species detected during 167 20-min unlimited-distance point counts during 3–24 February 1987 and from 19 January to 25 February 1988. To minimize confounding influences of seasonal changes (see Robbins 1972, Anderson et al. 1981, Rollfinke and Yahner 1990), point counts were completed during January and February, when species richness and abundance are essentially stable in the study area (F. R. Gehlbach, pers. comm.). Within each 20-min period, detections were recorded during four consecutive 5-min intervals (Robbins 1981a).

Point counts were conducted in twenty-two areas of woodland that were chosen because they were accessible and typical of those in central Texas with respect to floristic composition, areal extent (approximately 10–200 ha), and successional stage. For each of these areas, random starting points defined initial count sites. Subsequent sites were established by pacing at least 200 m from the first or previous site. Depending on its size, each area yielded from two to fifteen count sites. All count sites were established at least 200 m apart to minimize dependencies in the data from consecutive sites (see Blondel et al. 1981, Dawson 1981, Hutto et al. 1986). Most sites within a given area were about 300 m apart; individual areas were separated by 3–30 km. KJG began recording data when he reached a point 25 m from the next point-count site (at least 175 m from the previous site). This enabled him to record individuals that were present at a site but that, on his approach, stopped vocalizing or flushed without returning (Hutto et al. 1986). Only individuals that actually used woodland perimeters or interiors, either at the time of detection or within a few seconds thereafter, were included in this analysis. To minimize the chance for statistical dependencies among point counts, we did not include several species that were often audible or visible from distances exceeding 200 m (waterfowl, wading birds, Turkey Vulture [*Cathartes aura*], Black Vulture [*Coragyps atratus*], Red-shouldered Hawk [*Buteo lineatus*], Red-tailed Hawk [*B. jamaicensis*], American Crow [*Corvus brachyrhynchos*]).

Counts were not conducted when wind speed was >20 km/h (Robbins 1981b), air temperature was <0°C, more than a light drizzle fell, or when snow was on the ground. Point counts hampered by noises or activities of dogs, people, or large bird flocks were not used. Habitat and physical conditions varied somewhat among the 167 count sites (Gutzwiller

1991); in the present analysis, our intent was to identify relations that transcended such influences. We wanted to provide censusing guidelines effective for the entire range of conditions we encountered, so we did not analytically remove variation in mean richness or detection probabilities associated with these differences. KJG sampled once at 167 distinct but comparable sites to ensure statistical independence among point counts and to provide information for a greater variety of environmental conditions than repeated censuses at fewer sites would have permitted. Before arriving at each count site, KJG chose either to wear or remove the same orange vest based on the number of point counts necessary to balance each apparel condition (vest worn, vest not worn) among levels of the other independent variables in the study (count duration, site type [woodland perimeter, woodland interior], time of day, winter date, year [Gutzwiller 1991, 1993]). Influences of the vest on estimates of richness and detection probabilities were thus prevented from being confounded with effects from the other independent variables. Additional data-collection details are described in Gutzwiller (1991, 1993).

Statistical analyses.—We applied a square-root transformation to the richness estimate (number of species detected) for each count site to normalize error terms and stabilize error-term variances (Neter and Wasserman 1974, equation 15.11). For each apparel condition, a normal probability plot (SAS Institute, Inc. 1985a) indicated transformed richness values were normally distributed; variances for the transformed richness values for the two apparel conditions also were quite similar (1.79 for vest worn, 2.17 for vest not worn). To test for differences in mean richness associated with the two apparel conditions, type III sums of squares were computed with Proc GLM (SAS Institute, Inc. 1985b). Type III sums of squares enable one to assess more clearly the influence of a given effect because all other effects in the model are accounted for first. We tested whether mean richness differed between apparel conditions after controlling for variables used in an earlier general linear model for richness (count duration, site type, time of day, winter date, year, and associated interactions) (Gutzwiller 1991). Data for all forty-six species (see Gutzwiller 1991, Table 1) used in this original model were also used in the present richness analysis.

We used logistic regression to relate the presence (coded 1) or absence (coded 0) of a given species at a site to whether or not an orange vest was worn (VEST); this enabled us to test for differences in a species' detection probabilities associated with the two levels of apparel condition. For each species separately, variables found to be influential in previous analyses (Gutzwiller 1993)—count duration, site type, time of day, winter date, year, and associated interactions—were controlled for before assessing the influence of apparel condition. Analyses were performed with BMDPLR (stepwise) programs (Dixon 1988) and associated maximum likelihood ratio estimators. The indicator variable, VEST, was 0 when a vest was not worn and 1 when a vest was worn. To obtain a parsimonious description of associations, and to avoid spurious relations due to overfitting, each final logistic regression model for a species had to have (1) a significant ($P < 0.05$) χ^2 -to-remove statistic for each explanatory variable (actual P levels were 0.000–0.022), (2) nonsignificant goodness-of-fit statistics (actual P levels were 0.504–1.000), and (3) regression coefficients and associated standard errors (SEs) with small magnitudes (Hosmer and Lemeshow 1989) (actual coefficient magnitudes were 0.0002–1.8070; actual SE magnitudes were 0.1599–0.9290). The χ^2 -to-remove statistic is a measure of how well an explanatory variable is related to the dependent variable after the influences of all other explanatory variables in the model have been taken into account. Nonsignificant goodness-of-fit statistics for a model indicate that the model is an acceptable description of the observed data. Small magnitudes of logistic regression coefficients and their SEs indicate that the data have not been overfitted and that numerical problems such as zero cell count, complete separation, and collinearity have not affected estimates appreciably (Hosmer and Lemeshow 1989). Because VEST was not sig-

nificant for some species but was significant for others, we used χ^2 -to-enter statistics to report the outcomes of the analyses for all species; χ^2 -to-enter and χ^2 -to-remove statistics were identical when VEST was significant and included in the model.

For each apparel condition, we adjusted the detection probabilities and their associated SEs for other effects in each species' logistic regression model. Because a logistic curve is nonlinear, the variation in detection probability around the adjusted point estimate was not symmetrical. To compute the SE of an adjusted detection probability, we constructed a 95% confidence interval for the probability, divided each side of the interval by two to get one SE for each side of the interval, and then averaged these two SEs (cf Hosmer and Lemeshow 1989, D. A. Anderson, pers. comm.). To avoid zero cell counts and the imprecise logistic regression coefficients that result (Hosmer and Lemeshow 1989), only those species that were detected during more than 25% of the 167 point counts were used in the present analysis.

RESULTS

Thirteen species were detected during more than 25% of the counts; these species and the number of counts during which they were detected were: Red-bellied Woodpecker (*Melanerpes carolinus* 65), Northern Flicker (*Colaptes auratus* 61), Blue Jay (*Cyanocitta cristata* 69), Carolina Chickadee (*Parus carolinensis* 110), Tufted Titmouse (*P. bicolor* 51), Carolina Wren (*Thryothorus ludovicianus* 70), Ruby-crowned Kinglet (*Regulus calendula* 43), Eastern Bluebird (*Sialia sialis* 45), American Robin (*Turdus migratorius* 103), Northern Mockingbird (*Mimus polyglottos* 62), Yellow-rumped Warbler (*Dendroica coronata* 96), Northern Cardinal (*Cardinalis cardinalis* 117), and American Goldfinch (*Carduelis tristis* 60).

We did not find a significant difference in the number of species detected between apparel conditions. The least-squares means for the square-root transformed richness estimates (\pm least-squares SEs) were 4.54 ± 0.156 (vest worn) and 4.71 ± 0.167 (vest not worn) ($F = 0.54$, $df = 1$, $P = 0.462$, $N = 167$).

Logistic regression analyses indicated, however, that the detection of some individual species was related to whether or not a vest was worn (Table 1). The adjusted detection probability (\pm adjusted SE) for Blue Jays was lower when a vest was worn (0.144 ± 0.043) than when a vest was not worn (0.343 ± 0.066). But Brown's goodness-of-fit test for the Blue Jay model was significant ($\chi^2 = 7.43$, $df = 2$, $P = 0.024$), indicating that a logistic model may not be appropriate for the set of variables used. The Hosmer-Lemeshow goodness-of-fit test for this model was not significant ($\chi^2 = 7.43$, $df = 8$, $P = 0.491$), implying that the model's predicted values fit the observed data. Taking a conservative approach, we decided that the relation between Blue Jay detection probability and VEST could not be interpreted clearly. Nevertheless, the attained significance level for VEST ($P = 0.004$) suggests that additional field study of this association is warranted.

TABLE 1
 STATISTICS FOR LOGISTIC REGRESSION RELATIONS BETWEEN SPECIES' DETECTION
 PROBABILITIES AND WHETHER OR NOT AN ORANGE VEST WAS WORN (VEST) (N = 167)

Species	χ^2 -to-enter for VEST (df = 1) ^a	P
Red-bellied Woodpecker	2.14	0.144
Northern Flicker	0.01	0.927
Blue Jay	8.54	0.004
Carolina Chickadee	3.17	0.075
Tufted Titmouse	6.92	0.009
Carolina Wren	0.06	0.802
Ruby-crowned Kinglet	0.08	0.771
Eastern Bluebird	0.87	0.352
American Robin	1.81	0.178
Northern Mockingbird	0.19	0.662
Yellow-rumped Warbler	0.17	0.684
Northern Cardinal	1.13	0.287
American Goldfinch	9.26	0.002

^a A significant χ^2 -to-enter statistic indicated that if VEST was included in the model there would be a significant improvement in the model's ability to predict detection probabilities. For each species, a vest was worn during 87 point counts but not during the other 80 counts.

We found a marginal association between Carolina Chickadee detection and VEST (Table 1). The adjusted detection probabilities (\pm adjusted SEs) for Carolina Chickadees were 0.498 ± 0.058 (vest worn) and 0.655 ± 0.062 (vest not worn). Stronger relations were found between the detection of the Tufted Titmouse and American Goldfinch and whether or not a vest was worn (Table 1). For the Tufted Titmouse the adjusted detection probabilities (\pm adjusted SEs) were 0.169 ± 0.041 (vest worn) and 0.372 ± 0.061 (vest not worn); for the American Goldfinch they were 0.083 ± 0.032 (vest worn) and 0.236 ± 0.061 (vest not worn). Thus, for all three species exhibiting relations, when a vest was worn detection probabilities were lower.

DISCUSSION

The results argue that the Carolina Chickadee, Tufted Titmouse, and American Goldfinch were repelled by a hunter-orange vest. We are not aware of any previous work that documents such apparel-color influences. Negative and positive chromotropic responses to researcher apparel have the potential to generate inaccurate assessments of avian behavior, habitat use, and abundance. Efforts to manage habitats and populations may be thwarted if decisions are based on data with serious color-induced artifacts.

The relations found for the Carolina Chickadee, Tufted Titmouse, and American Goldfinch expand and confirm current knowledge about the color orange as an avian repellent. Hess (1956), Kear (1964), and Oppenheim (1968), for example, demonstrated that orange elicited fewer pecks by Mallard (*Anas platyrhynchos*) ducklings than did other colors. Further, orange appears to have more potential than other colors as an aversive stimulus to prevent Mallards from landing on oil spills (Lipcius et al. 1980).

The species-confidence hypothesis (Burley et al. 1982; Burley 1985b, 1986a) asserts that birds prefer colors that are typical of their own species and that they avoid atypical colors. Adult male Zebra Finches (*Poephila guttata*) have red-orange beaks and orange legs, and female Zebra Finches preferred red-banded males over unbanded, or orange-, blue- or green-banded males (Burley et al. 1982; Burley 1985a, 1986a, b). Sexually monomorphic Double-bar Finches (*P. bichenovii*) have bluish-gray legs and beaks, and both sexes preferred blue-banded members of the opposite sex over both unbanded and red-banded individuals (Burley 1986a). Wilson et al. (1990) found that Adelie Penguins (*Pygoscelis adeliae*) ignored black devices that were attached to their black-feathered backs, which also supports this hypothesis.

Based on the species-confidence hypothesis, it thus seems plausible that species with red or orange on their bodies would not be repelled as easily by an orange vest as species without these colors. Of the thirteen species we studied individually, seven (Blue Jay, Carolina Chickadee, Tufted Titmouse, Carolina Wren, Northern Mockingbird, Yellow-rumped Warbler, American Goldfinch) did not have shades of red or orange on their bodies; the other six species (Red-bellied Woodpecker, Northern Flicker, Ruby-crowned Kinglet, Eastern Bluebird, American Robin, Northern Cardinal) did. Three (43%) (Carolina Chickadee, Tufted Titmouse, American Goldfinch) of the seven species without red or orange appeared to be repelled by the orange vest, whereas none of the six species with red or orange on their bodies had detection probabilities that were associated with VEST.

Johnson et al. (1993) found that during the breeding season female American Goldfinches were attracted to males with brighter orange bills, and that females preferred males with orange leg bands. Thus, orange may repel American Goldfinches only during winter when orange is not part of this species' typical coloration. Female American Goldfinch preference for males with orange bills during the breeding season is consistent with the species-confidence hypothesis because females also have yellow-orange bills at this time (Mundinger 1972, Johnson et al. 1993). Considering the American Goldfinch data from both Johnson et al. (1993) and

the present study, avian color preferences and tolerances probably depend in part on context. Preference for a particular color may depend, for example, on whether the objects with that color are leg bands on a conspecific or food items (N. Burley, pers. comm.).

Perhaps the person-vest combination was more repellent than the orange garment alone. That is, some species may be more shy around people, have less contact with people, or both, compared to other species, and wearing an orange vest may elicit more pronounced avoidance of people by timid or wary species because a person wearing such a vest would be more conspicuous (N. Burley, pers. comm.). The three species that appeared to be repelled by the orange vest, however, are easily approached (when an orange vest is not worn) and common in human-dominated areas. Still another possible explanation for our results may be that the three species that exhibited a vest effect are innately averse to orange (cf Smith 1975), although female American Goldfinch preference for males with bright orange bills casts doubt on this idea for this species. Overall, our results are consistent with the species-confidence hypothesis, but context and innate responses also may have influenced the effects of the vest.

The different associations between detection probability and VEST found among species in this study illustrate that biases and artifacts can arise from chromotropism. Although we did not design the study to discern the mechanism(s) responsible for the patterns we observed, knowledge of the associations themselves is valuable because it can enable researchers to design more valid research. A clear benefit would be more accurate inferences.

Investigators can use several strategies to avoid or minimize biases and inaccuracies originating from chromotropism. A pilot project for one's study area would be useful to determine which, if any, species are influenced by clothing color. Efforts to assess these relations for a few or many species would be outweighed by the information gained and the consequent improvement in study design. Colors that are suspected or known to attract, repel, or cause aberrant behavior should not be worn. If such colors are necessary as a safety precaution, as hunter orange was for KJG, then clothing with those colors should always be worn, their effects should be estimated, and the results should be interpreted accordingly. If influential colors must be worn for safety by some investigators but not by others in a single study, potential problems in interpreting the results can be ameliorated by accounting analytically for this source of variation. For example, whether or not apparel of a particular color is worn could be considered a fixed-effect factor (*sensu* Zar 1984) in analysis of variance, analysis of covariance, ordinary least-squares regression, or logistic regression. Some species may react to specific colors, whereas others in the

same area may not. Ideally, researchers should wear colors that affect the fewest species. Perhaps the best way to achieve this is to wear dark drab clothes or camouflaged garments so that one's detectability is reduced.

ACKNOWLEDGMENTS

We thank F. R. Gehlbach for help with winter-call identification; D. A. Anderson and R. S. Cochran for statistical advice; J. Blondel, N. Burley, F. F. Rivera Milan, J. Smallwood, and an anonymous reviewer for comments on the paper; A. Gordon for help with finding study areas and identifying winter calls; and C. Coody for finding study areas. Numerous central Texas landowners kindly granted KJG permission to work on their property. Funding was provided by the Baylor University Research Committee.

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